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Effect of the Kharkhe Storage Dam on Vulnerability of Downstream Land and the Kharkhe Bondary

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Abstract: River boundaries, as defined by the state law, comprise the land along and surrounding riverbanks expected to be inundated or flooded during flood events of a 25-year return-period. Construction of large water structures such as dams across rivers may lead to considerable decrease in the flood discharge proportionate to structure size which will in turn result in lower flood probability. Assessment of the vulnerability of river boundary is of great importance due to their rich soil and easy access to irrigation water which makes such riverbank farms economically valuable especially in dry areas. The results of such assessment can be used in land use planning. For the purposes of the present study, a reach of 190 km was selected along the banks of the Karkheh River downstream the Karkheh Storage Dam in southern Iran. Estimations were then made of river flood events prior to constructing the dam with return periods of 2 to 100 years and their corresponding post-construction values for the same periods. Values of flood inundation of the river banks were determined for flood events with different return periods. Using the values thus obtained, the vulnerability curve was plotted for various flood probabilities before and after constructing the dam. It was revealed that the construction of the dam had reduced the size of the river boundary due to full control of 2 to 25-year floods and, thus, saving the river banks from flood inundation. However, the same pattern was not observed for flood events with return periods above 50 years. Therefore, it is advised that the Karkheh riverbanks should be planned for land uses that can tolerate the risks of such long term flood events. Also, must not be considered for residential developments or for high-cost establishments.

Key words: Flood . floodplain . karkheh river . flood vulnerability . flood inundation . river boundary . hec ras

INTRODUCTION

River boundary is defined as the stretch of land on the banks of a river that may be inundated during flood events with 25-year return periods [1, 2]. The use of such land areas is prohibited by relevant regulatory bodies. However, even land areas beyond river boundaries are always associated with risks (flood inundation), calling for flood risk management provisions when they are planned for use. To achieve a risk management model for these land areas, the associated risks must be assessed appropriately [2]. No considerable changes typically take place in the course of time in river boundaries which are determined under natural conditions from hydrometric data records. The boundaries particularly in the case of land areas normally inundated during flood events of 25-year return period may, however, undergo changes as a result of upstream storage dam construction depending on the impact of such dams on flood control. In the case of rivers such as the Karkheh whose 25-year discharge shows significant differences before and after constructing the dam [3], considerable changes may occur in river boundaries. Since river banks are normally fertile land areas, proper land use planning requires risk management considerations.

Numerous studies have been performed on floodplains due to their significance in river engineering, but the effect of dams on river banks has not been adequately investigated. Jongman Rob [4] studied land use and floodplain management of the Rein River in the Netherlands using data collected from the river bed and its floodplains to find floodplain land use highly effective in river erosion and sedimentation patterns. Liu and Yu [5] investigated the effects of Danjingko hydroelectric dam built in 1973 across the Hanjiang River. They showed that dam construction considerably reduced water level values and rescued

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large land masses from flood inundation but increased riverbed scouring due to reduced sediment load and increased erosion power of water. Ripendra [6] carried out floodplain analysis and flood risk assessment simultaneously with a study of river hydraulics, topography and floodplain land use along the Rakhandal River (Nepal). In this study, he used the one-dimensional Hec-Rec model for flow simulation and yielded flood risk values for different parts of the floodplain on a GIS map. Saad [7] surveyed the changes in the morphology and floodplain of the Nile River resulting from the construction of the Great Aswan Dam in 1963. It may be concluded from the results of the studies cited above that although land use planning and floodplain management have considerable effects on alleviating flood induced damages in riverbank land areas, the effects and the effectiveness of storage dams are more tangible on the vulnerability of riverbanks and downstream areas, the effects being a function of the characteristics, location and hydrological behavior of the river stretch downstream the storage dam. In the present study, this issue was investigated for the downstream and riverbank land areas at the water tail of the Karkheh Dam in an attempt to determine the effects and effectiveness of the dam in this area.

MATERIALS AND METHODS

The study area: The Karkheh River flows in the southwestern part of Iran and ranks the third largest river after the Karoon and the Dez. It runs over a course of 900 km (from its point of origin to its exit from Iran) and has the largest watershed of around 50,000 square kilometers among the rivers flowing in Iran. The study area includes around 190 km of the river course starting at 13-km downstream the Karkheh Storage Dam (the Paypol hydrometric station) to Hamidiyeh Diversion Dam running along the north-south direction. The river heads toward west after passing through Hamidiyeh Township to enter the Azadegan Plain (Fig. 1) [8].

Starting from the Paypol to downstream stretches of the Shoosh City, the river follows a braided pattern. After a short distance from the Shoosh City (exactly after Sheikh-Shojaa Village), the river changes its course toward southeast and, due to the alluvial nature of its bed, follows a meander pattern by about Elhaie Village. After this village and as a result of striking the Zeinolabedin anticline, the river course turns along the northeast-southwest direction continuing as far as the Hamidiyeh Regulatory Dam. The river flow is measured and recorded at three hydrometric stations (Paypol, Abdolkhan and Hamidiyeh) in the study area which have made available good, long-term data. The Paypol Station was selected as the reference station in the present study. According to hydrometric records from the Paypol Station, the annual maximum, average and minimum discharge rates of the Karkheh were 358, 164 and 72 m^3/s before constructing the dam (1999). After constructing the dam, however, the river discharge was regulated so that its six-year (1999-2005) average was reported to be 76 m^3/s. The maximum flood prior to dam construction had been to be reported to be 5222 m^3/s for the event occurring in the wet year 1973-74 [9].

MATERIALS AND METHODS

For the purposes of the present study, use was made of topographic maps on the 1:50000 scales

Fig. 1: Schematic view of Krakheh Watershed and its tributaries

(published in 1964) as updated in 1998-99 by ground surveying. For identification purposes, the initial plan of the river in 1998-99 (before the dam was built) along with 210 cross sections taken at varying distances were used. Additionally, bed samples taken from bed sediment at these sections were used. Using these samples, sediment particle size curves were prepared to estimate roughness coefficient. Hec-Ras software was used for flow simulation.

In order to determine the general geometric shape of the river, a number of previous studies and the literature including those specifically carried out for the Karkheh River were collected and consulted. These were used to determine the general shape of the river over the study area and plotted in the AUTOCAD environment on a scale of 1:50000. The cross sections taken from surveying were laid out on the longitudinal profile mentioned above. Flood discharge statistics from the three existing stations in the study area were collected and controlled with respect to their validity and accuracy. Statistical tests were also performed for data reconstruction where gaps were observed and a homogeneous 52-year statistical period (1947-99) was obtained for the stations. The Paypol hydrometric station was used as the reference station because of its reliable data. In the next stage, the 52-year statistics were extrapolated with different probability distributions. Using the selected (gamma) distribution, estimations were made of flood discharges with varying return periods [9]. River flow simulation for different flood events was accomplished using the Hec-Ras in the one-dimensional mode for a steady flow. In addition to flow data, river geometric data including roughness coefficient, river shape and cross sections were also used to run the software. These data were obtained as briefly described below:

Roughness coefficient: Direct measurement of particle diameter (particle-size curve) and empirical formulas were used to determine roughness coefficient. For this purpose, the particle-size curves for all cross sections taken were drawn in order to extract the diameters d_{50}, d_{65}, d_{75} and d_{90}. Figure 2 presents one such curve as an example. To obtain the roughness coefficient for the river, the four more locally common methods of Strickler, Miller, Kooligan and Lane were applied. Based on river conditions, comparisons with existing tables and expert judgments of the river, estimations by Miller formula taking d_{90} sedimentary particles diameter seemed to render a more logical estimate of the four. It must be mentioned that previous studies of the Karkheh River had assumed roughness coefficients of 0.035 to 0.040 as the average for the whole river [9].

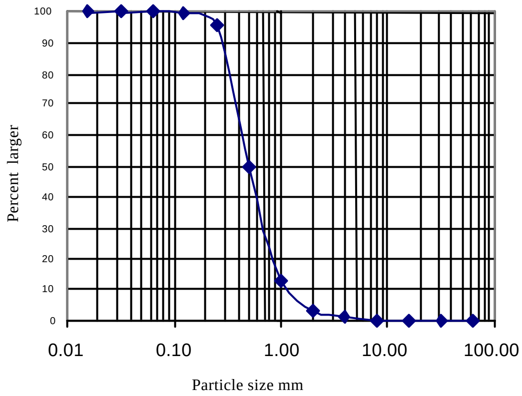

Fig. 2: Particle-size curve for one example cross section

Introducing cross sections into the model: For accurate introduction of the location of each section into the model, the (UTM) coordinates of the two ends of each section were obtained and then integrally inputted into the model followed by independent redefinition of the taken data from each section. The spaces between sections were determined from the AUTOCAD-prepared map and submitted in a file into the model.

Introducing the river pattern into the model: River shape and pattern can be introduced into the model in either of two ways. In the first method, the drawing environment of the model is invoked to draw the pattern directly into the model. According to the second method, the model extracts the river pattern from an input file containing the details of the whole river course obtainable in the AUTOCAD environment. We employed the second the method.

Once the above parameters had been introduced into the model and the boundary conditions (normal depth) had been defined, the water level profile was determined for different flood scenarios and then, the results were introduced to the AUTOCAD software for making maps. For each flooding scenario, inundated regions were identified from the contour curves and the values of water level at each section. The area of each flood inundated region for different flood events between consecutive sections was measured. The flooding regions for different probabilities and for flows before and after constructing the dam were independently drawn and the curves thus obtained were used to determine the level of reduced flooding risks in each case.

RESULTS

Employing the method selected in this study, the values for flood discharge with return periods ranging

Table 1: Values of flood discharge of the Karkheh River at Paypol Station with different return periods before and after construction of Karkheh Storage Dam

	Return period				
Time	100	50	25	10	2
Before dam construction	5523	4925	4313	3469	1739
After dam construction	4670	3077	1000	420	130

between 2 to 100 years were obtained for the stage prior to dam construction along with corresponding values for the stage after (Table 1).

Table 2 presents a summary of the values of sedimentary particle diameter as well as the values of roughness coefficient obtained from Miller's formula. Analysis of particle diameters along the river course revealed a declining trend in particle diameter along an upstream to downstream (around Hamidiyeh) sections. The maximum d_{50} particle diameter observed was 48 mm and belonged to the K3 section at a distance of 2 km from the onset of the study area (near Naderi Bridge) while the minimum observed was 0.18 mm, which belonged to K213 section around Hamidiyeh area. The average d_{50} sediment particle was 16.4 mm as shown in Table 2. The same also holds true for values of roughness coefficient. Upstream areas had a higher roughness coefficient due to higher particle size and downstream areas had a lower roughness coefficient due to their smaller particle size. The maximum roughness coefficient was 0.044 at upstream initial sections and its minimum was 0.028 at final downstream sections, with a weight average roughness coefficient of 0.037 for the whole course.

The curve for inundation vulnerability for different probabilities is presented in Fig. 3.

As shown in Fig. 3, the inundation curves are nonlinear both before and after dam construction. The reason for this may lie in the topography of the land around the river. This is because increasing the values of water level in mountainous sharply sloping regions does not cause considerable increases in inundation vulnerability values. This is while in plains and low sloping land, increasing values of water level will be associated with correspondingly greater inundated areas. By comparing the two curves, it can be concluded that there has been a reduction in the inundation vulnerability after dam construction for different water level scenarios albeit with varying rates in this reduction for the different probabilities studied. Reduced vulnerability for the middle probabilities (around 0.04 to 0.1) was very high but for lower or extremely high probabilities, the vulnerability reduction rate was low. This is because for low probabilities (long return periods) when flood volume is high, the dam has a little effect on flood control. Under these circumstances, flood flows over dam gates and spillways, thus the two curves become better approximants and the flood control effect of the dam almost vanishes. For high probabilities of less than 0.2 (return periods of less than 5 years), little water flows over surrounding land due to low volume of flood water, most of the flow being conveyed through main channels. These curves, therefore, indicate that the effect of the dam in flood control and in reducing inundation vulnerability is essentially for medium flood probabilities (return periods). Assuming a flood probability of 0.04, or a return period of 25 years, in Fig. 3 which is used to determine river boundaries, we can draw a vertical line crossing the two curves and thus divide the inundated surrounding land into the two parts of land inundated before and after dam construction. The difference between these two parts will indicate the area of the surrounding land that will be saved from inundation. Using Fig. 3, it is evident that area of the river boundary reduced from the original 52,000 ha before dam construction to 10,000 ha after dam construction, thus saving 42,000 ha from inundation vulnerability. This area can be allocated for appropriate land uses with provisions for flood risk management practices.

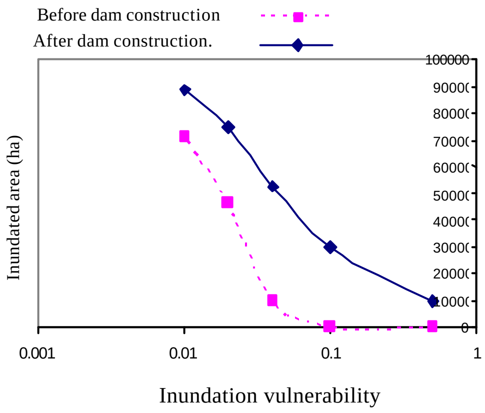

Fig. 3: Inundation vulnerability curve for the banks of the Karkheh before and after dam construction

DISCUSSION AND CONCLUSION

The construction of Karkheh Storage Dam has reduced flooding risks in downstream land. The trend in risk reduction is not uniform for all flood probabilities. Inundation vulnerability almost tends toward zero for very low probabilities (100-year return periods) and is almost negligible for very high probabilities (2-year return periods). However, flood risk reduction for land

Table 2: Summary of particle size analysis for different sections of the Karkheh River

Statistical parameter	Particle diameter (mm) D50	D65	D75	D90	Roughness coefficient N
Max.	48.00	54.00	60.00	64.00	0.044
Min.	0.18	0.23	0.25	0.38	0.028
Mean	16.37	21.78	26.53	39.93	0.037
S.D.	15.12	18.37	21.86	27.19	0.010
C.V.	0.92	0.84	0.82	0.68	0.271

areas which used to be normally inundated with medium return periods (5 to 25 years) has drastically reduced. A large portion of the surrounding land can, therefore, be allocated to different land uses if proper flood risk management measures are used. Our findings match those of Jongman Rob [4], Liu and Yu [5] and Ripendra [6]. The only difference relates to flood return periods which depends on the characteristics of the storage dam studied. In addition to the parameters described above, we also drew flood vulnerability curves and identified on the map the land areas that used to be inundated. Based on our findings, it is suggested that given the reduced vulnerability in the rescued land areas surrounding the Karkheh River banks downstream the storage dam, they can be allocated to appropriate well-defined land uses.

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